OBSERVATIONS ON THE REACTIONS OF CRYPTOBRANCHUS AND NECTURUS TO LIGHT AND HEAT.

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During most of the time for the past four years the writer has had one or more specimens of the giant salamander (*C. allegheniensis*) in captivity in the laboratory, and the tendency of these animals to seek the darker parts of the tanks in which they were confined, or to crawl under any sufficiently large object that might be present, led to the experiments which are summarized in the present paper.

The experiments with *Necturus* were performed on five individuals of average size, though most of the light experiments were carried on upon one individual.

Four large specimens of *Cryptobranchus* were used for both sets of experiments, the heat experiments being nearly all performed after the completion of the light experiments.

In the light experiments three sources of illumination were employed: A sixteen candle-power incandescent electric lamp, so shaded that the light could be thrown on any given part of the animal without illuminating the rest of the tank; the direct rays of the sun, reflected from a small mirror; and an ordinary arc, projection lantern, which was set up at the side of the tank, so that a narrow beam of light could be reflected from a mirror into the water.

In the color experiments red and blue globes were used with the incandescent lights, and with the other two methods of illumination plates of red and blue glass were introduced into the white rays from the sun or from the electric arc.

It was found, by the use of the spectroscope, that the red plate gave an almost pure red, while the red bulb gave, besides the red, some yellow and green rays. The blue plate gave the entire spectrum except the dark green, yellow and yellowish red; the blue bulb gave the entire spectrum, which apparently differed

from that of the ordinary white bulb only in intensity. Owing to this impurity in the colors, especially the blue, the observations with the red and blue lights cannot be given much weight; some of the observations will, however, be briefly given below.

It was found that both with *Cryptobranchus* and *Necturus* the responses to light were much more marked for the first ten or a dozen stimulations than for succeeding stimulations, so that it was necessary, on account of this loss of sensitiveness, to make only a comparatively short series of experiments at any one time. Ordinarily these animals will lie for many minutes or, possibly, even hours without the slightest motion, so that their reaction to stimuli at these times is too evident to doubt; but occasionally, especially at night, they become restless, and it becomes necessary to postpone experimentation. In each case where no reaction was obtained within two and one half minutes the reaction was recorded as "none." Since the animals under observation were at all times covered with several inches of water it seemed unnecessary to use any form of heat screen, as this depth of water would absorb all heat rays from the artificial lights if not from the solar illumination.

Reactions of Cryptobranchus to Light.

The effect of a ray of white light when thrown on different parts of the body was first tried. It was found that all parts of the body are sensitive to white light, but that the tail is by far the most sensitive region. While enough experiments were performed to show that the middle regions were more or less sensitive to white rays, it was the head and tail that were chiefly studied in their reactions to light stimulation.

When a ray of white light was thrown upon the tail the response was, in very many cases, immediate, and consisted in a quick forward movement of the animal until the tail was removed from the illumined area. In almost no cases among many trials was the response delayed for as much as a quarter of a minute, the average time for a response being about three seconds or less. The extreme sensitiveness of the tail of this animal to light stimulation is quite remarkable, and the response is, in all cases, exactly the same.

In about half of the experiments where light was thrown upon the head of *Cryptobranchus* no response was obtained even at the end of two and a half minutes or longer, and in no case was a response obtained in less than nine seconds: however, sufficient undoubted responses were obtained to justify the statement that the head of the animal is sensitive to white light. The response in this case, when it came at all, was invariably shown by the animal's backing away from the light.

The responses were about as sudden and as strong when the incandescent light was used as when the much stronger illuminations were employed; this may have been due to the fact that when the rays from the sun or the arc light were used the tank was partially illumined by diffused light, while in the other case there was no light except the small circle that came from the shaded incandescent bulb.

That *Cryptobranchus* is sensitive to white light of even weak intensity seems proven by the fact that the animals seek the darker parts of their tank in ordinary diffused light.

The results obtained with the red and blue lights were not so definite as those with the white light, and, as has been previously stated, may have but little value. With the red plate which gave, with the arc light, a strong, pure red illumination, no responses at all were obtained, either from head or tail stimulation. The incandescent light with the ruby globe, while not so strong a light, produced, in most cases, decided responses; this was possibly due to the fact that the light was not nearly so pure a red as that given by the plate. The responses were of the same character as with the white light, the difference being one of rapidity.

In no case was the response to a stimulus instantaneous, as with the white light, but in several instances reaction took place, when the tail was stimulated, within two seconds. As with the white light, the head was much less sensitive than the tail.

The reactions to blue light were of the same character as with the other forms of illumination, but were more rapid than with the red light. The apparently greater sensitiveness to blue than to red light may have been due simply to the greater purity of the latter color.

Reactions of Necturus to Light.

The same kinds of experiments were tried with *Necturus* as with *Cryptobranchus*. All parts of the body seemed sensitive to white light, but in this case the head was more sensitive than the tail, the withdrawal from the circle of illumination being instantaneous, in many cases.

The effect of illumination from below was also tried with *Necturus*, the animals being placed in a glass aquarium which was shaded from above, while a beam of sunlight was thrown on the ventral regions of the body. All parts of the ventral surface were sensitive to this form of stimulation, but the head was, in this case, much less sensitive than the tail. The responses as a whole were neither so quick nor so strong as when the light fell upon the dorsal regions of the body.

A beam of red light produced by the same red plate that was used in the experiments upon *Cryptobranchus* produced no reactions that were definite enough to be of value. The red, incandescent bulb, on the other hand, caused fairly strong reactions, those from the head and tail being of about the same suddenness.

The reactions to blue light, whether produced by the plate or the incandescent bulb, were much more decided than those to red light; the average reaction time for the head and for the tail was about the same.

No experiments were tried to determine the effect of red or blue light upon the ventral side of the body, either with *Cryptobranchus* or with *Necturus*.

That it is not the organs of the lateral line system that respond to these light stimuli seems probable, at least in *Cryptobranchus*, from the fact that the head region, which is most abundantly supplied with the organs, is less sensitive to light than is the tail. In *Necturus*, when the light came from above, the head gave the most sudden responses; but when the light was from below the tail was more responsive than the head. This would seem to indicate that the more rapid response from the head was due to the sensitiveness of the eyes, though why this should be the case with *Necturus* and not with *Cryptobranchus* is not apparent.

Parker ('05) thinks that the sensitiveness to light of young lamprey eels is due to stimulation of the ends of the spinal nerves in the skin; this may be the case here also. He found ('05) that in the ammocœtes, as in *Cryptobranchus*, the tail is the most sensitive part of the body, the response being negative. In the frog, on the other hand, he found ('03) the reaction to be positive. Just as it is of value to the young lamprey, on account of its burrowing habits, to have a tail that is sensitive to light, so is the sensitive tail probably of value to the giant salamander because of the animal's habit of concealing itself under objects in its native haunts. The fact, as I have already shown ('05), that the eyes of this animal are probably not very sensitive, may have something to do with the unusual sensitiveness of the tail.

Thermic Reactions of Cryptobranchus.

The temperature experiments were made upon four adult specimens, the same ones that were used in the light experiments.

When taken from their tank, where the water was at 18° C., and put into water at 33° none of the four animals showed any signs of being aware of the change of medium; the same negative results were noted when they were changed from water at 5° to water at 26°. On one occasion, however, they showed slight signs of discomfort when put from water at 14° into water at 26°.

Removal of the animals from water at either 18° or 26° to water at 42° resulted in the most violent struggles, beginning after an immersion of two or three seconds and lasting, usually, for a minute or more, or until the animal was completely exhausted. The violence of these struggles was quite remarkable, though less marked in some cases than in others. In some instances the struggles continued until the animal was completely exhausted and turned belly side up as though dead; in other cases the struggles gradually ceased until the animal lay quietly in the warm water. Two of the animals died soon after the experiments, probably as the result of their experiences, as they had seemed perfectly healthy before.

Removal from water at 26° to water at 5°, or from water at 18° to water 0° caused no reaction, although, in the former case,

there was a decrease in temperature of 21°. Neither did an increase of 21° or more cause any reaction unless the higher temperature reached 40° or more. It would seem, then, that *Cryptobranchus* is not sensitive to considerable changes in temperature, but is very seriously affected by a temperature only slightly higher than that of the human blood.

Thermic Reactions of Necturus.

As might be expected, perhaps, from its having gills, *Necturus* proved to be more sensitive to temperature variations than was *Crytobranchus*.

When transferred from water at 0° C. to water at 18° three of the five animals showed little or no reaction, but the other two darted about the tank in a curious, spasmodic way quite different from their usual motions. When transferred from water at 18° to water at 32°, three of the animals again showed but little activity, while the other two struggled quite violently. When put into water at 42° from water at 32° or lower, all of the animals struggled as violently as did *Crytobranchus*.

When put into water at 4° from water at 32° two of the animals again showed marked activity, while the other three were scarcely affected. A very short stay in the warm water was sufficient to completely exhaust all of the *Necturus*, so that they turned belly side up, but when returned to water of moderate temperature they soon recovered.

Necturus is apparently sensitive to considerable changes in temperature, both rising and falling, as well as to the higher temperatures to which *Crytobranchus* responded.

Other and more accurate experiments along these lines suggested themselves, but on account of the lack of the necessary facilities they had to be postponed.

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